a highly non-additive manner that the qualitative physics can only be accurately determined through a highly detailed molecular theory.
We find that charge regulation stabilizes micellar domains over a wide range of pH by reducing the local charge in the aggregate at the cost of chemical free energy and gaining in the van der Waals attractive interactions. The balance of interactions in this highly inhomogeneous environment determines the boundaries between different carrier and release morphologies. We predict the formation of polymer micelle phases based on the proper choice of solution pH and salt concentration, and one can use these predictions to provide design guidelines for the creation of responsive polymer delivery systems presenting self-organized patterns with the desired functional properties.

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Red Blood Cell Behavior within the Exclusion Zone
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Various hydrophilic polymers have been reported to induce the formation of an exclusion zone (EZ) at their surface, which is devoid of particles and may extend to several hundred microns. It has previously been suggested that even cells may be excluded from the vicinity of the gel, thus raising the possibility of developing microscale cell-separation technologies. Here we explored the behavior of red blood cells (RBCs) in the vicinity of Nafion with the aim of devising a cell-separation method and of understanding the microscale mechanisms of EZ formation. We assembled a PDMS-based microfluidic device housing a 1-mm diameter, 50-micron thick cylinder of Nafion. A suspension of RBCs, prepared from anti-coagulated whole human blood by repeated washing/resuspension in PBS, was infused in the device. The position, shape and spectral properties of RBCs were followed with brightfield video microscopy. Contrary to expectations, RBCs were not excluded from Nafion surface. Rather, a three-phase process of aggregation, lysis and discoloration propagated gradually across the stationary RBC suspension from the Nafion surface towards distal regions. During the discoloration phase RBCs turned brown, pointing at the possibility of acid-hematin formation. Microscpectroscopy measurements supported this hypothesis. Thus, the vicinity of fresh Nafion surface is a highly acidic environment. The spatial and temporal propagation of the process suggests that protons diffuse out of the polymer. Soaking Nafion extensively in PBS resulted in the disappearance of the RBC-associated phenomenon, indicating that the thermodynamic driving force of particle exclusion is most likely the presence of a steep proton gradient between Nafion and the surrounding buffer solution. Due to its high acidity, unequilibrated Nafion has limited applications in cell-separation methodologies.

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Solid-Binding Peptides as a Biotemplate for Li-Ion Battery Electrodes
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Li-ion battery electrodes composed of electroactive materials at the nanoscale level show higher capacity and energy density over macroscale structures. However, nanoscale battery materials are prone to aggregation upon cell cycling, which reduces the specific capacity and coulombic efficiency, thus, leading to poor cycling stability. Using a biotemplating approach for electrode fabrication presents opportunities that may overcome aggregation and improve conductivity through introduction of biological nanoscale templates that would precisely control the position of electroactive nanoparticles in intimate proximity with conductive material and provide structural support upon cycling. Engineering of nanoscale bridges between electroactive and conductive material is done using solid-binding peptides (SBP) that have specific binding affinity for the materials of interest. In our study, SBP for cathode material Li2Mn3NiO8 (LMNO) was isolated using M13 bacteriophage through Phage Display procedure (New England Biolabs®). The nature of binding affinity between the peptide and the active material was determined through site-directed mutagenesis of specific amino acids in the peptide sequence. Binding peptides for LMNO and multiwalled carbon nanotubes (MWCNTs) are combined to form bifunctional peptide that serve as a nanobridge to connect two materials with synergistic properties. In this presentation I will discuss research on determining how SBPs bind to electroactive materials, and I will also show the impact that multifunctional SBPs have on improving battery electrode performance.

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Current Fluctuation Analysis in a Protein Nanopore
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Current fluctuation analysis has been widely used over the recent years to study the kinetic effects of different biological systems like neuronal networks or biomembranes. In particular, noise analysis has been successfully employed in protein ion channels to investigate the transport mechanisms that control the channel function. In this work, current fluctuations are analyzed in a protein nanopore, OmpF from E. coli. The study is performed for different electrolytes, including KCl, LiCl, $MgCl_2$, and $CaCl_2$, over a wide range of concentrations and voltages. Previous studies addressing current fluctuations in OmpF investigated the pH titration of the channel residues by analyzing the Lorentzian-like shape of the power spectral densities [1]. A complementary approach is followed here, based on the noise studies of Hoogerheide and colleagues in synthetic nanopores [2]. Special attention is paid to the additional white noise seen in the low frequency range of the power spectral density. The average noise scales with the square of the dc current, showing that this frequency−independent excess noise originates from conductance fluctuations. These fluctuations are analyzed here in terms of the ionic concentration to disclose the different transport mechanisms occurring in OmpF channel.
[1] E.M. Nestorovich et al. (2003) Biophys. J. 85:3718−3729
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Naturally Synthetic: Using Biology to Improve Technology
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Nature has a diverse toolkit that can be utilized to address a broad array of problems. Among these tools are DNA, lipids, polysaccharides, and proteins, each of which has been used for direct applications from sensors to electronics. Among these macromolecules, proteins represent nature's most diverse polymer with a range of functionality determined by 20 different natural building blocks. The functionality of proteins is determined by their amino-acid content and structure. For instance proteins that bind to metal ions for biomineralization typically express higher levels of amino acid residues containing carboxylate side groups or histidines and cysteines. The amino acid makeup of a protein or polypeptide determines its properties (whether it can bind to metal ions, protein surfaces or nearly any other functional material because proteins can be designed to bind to a large number of materials).
The focus of my group is to identify functional polypeptides and use these to improve the properties of technologically relevant materials. Our lab uses a technique called phage display in order to identify solid binding polypeptides that are specific for binding to and the mineralization of electroactive materials and use these materials to prepare new lithium ion batteries. Once peptides are identified, they will be synthesized and combined with other peptide chains that have already been isolated that bind to carbon nanotubes (CNTs) to make multifunctional polypeptides. My research is multidisciplinary and involves the integration of biology, biochemistry, synthesis and nanomaterials science in order to address significant technological problems.